Central California Coast
Interagency Land Cover Mapping Project
Proposal

Draft June 18, 2003

Summary

This proposal seeks funding for a collaborative effort between state and federal agencies to develop improved land cover data for the Central Coast of California. Land cover data includes natural vegetation, agricultural lands, and urban areas. This project will also test newly developed statewide standards for vegetation mapping and demonstrate a collaborative, cost-sharing effort between state and federal agencies. For example, by sharing the costs of imagery acquisition, staff estimates that the Department of Fish and Game, the Department of Forestry and Fire Protection, and the U.S. Forest Service can save $650,000 over the costs of mapping this area individually. Additional cost-savings are likely, due to shared fieldwork and delineation of vegetation polygons.

The project area includes all of Monterey, San Benito, and San Luis Obispo counties and the coastal range portions of Fresno, Kings, and Kern counties. This 6.4 million acre area will be mapped at two levels: a mid-scale (1: 40,000) product and a fine scale (1:24,000) product. The mid-scale product will cover the entire project area, while the fine-scale product, requiring more field validation, will focus on smaller, high priority areas.

The total cost is approximately $2.39 million, although this total may be substantially reduced depending on availability of existing suitable aerial photography. The project can be funded for one or two sub-areas only, with total cost as low as $300,000, if funds for the entire project area are not available.

Long-term Objectives

An interagency team of six state agencies, three federal agencies, the University of California, Riparian Habitat Joint Venture, and the California Native Plant Society has developed this proposal. These organizations operate under a June 2000 Memorandum of Understanding related to cooperative vegetation and land cover mapping and classification throughout California. The purpose of this MOU is for the signatory organizations to work collaboratively in:

- Developing common standards for vegetation and land cover data content, data capture methods, field procedures, accuracy assessment and documentation
- Completing a hierarchical vegetation classification system adaptable to varying goals of the signatories and improve vegetation and habitat classification and crosswalks between systems
- Completing and maintain a vegetation map of all public and private lands in California on a regional basis through interagency cooperative efforts

as the basis for vegetation inventories and assessments of habitats, including detection of changes

This interagency team has recently completed the development of statewide land cover mapping standards and it has created mapping crosswalks between existing classification systems. The team now plans to test these standards in a realistic mapping effort. This will help refine the standards, develop realistic ways for agencies to work together, and set the stage for improved land cover mapping throughout the state. In the long-term, the results from this project will guide future collaborative mapping efforts to cover all other parts of the state.

Short-term Objectives

The specific objectives of this proposal are to:

1. Test land cover mapping standards for feasibility and cost-effectiveness, using the Central Coast region as an example
2. Develop and test a process for multiple agencies to reduce overall costs and collaborate on an integrated land cover mapping effort
3. Produce an improved land cover GIS data set for the Central Coast region, with medium-scale data covering the entire project area and fine-scale data in select priority areas.

Importance of Land Cover for Natural Resource Agencies

The primary focus of this land cover mapping effort is to identify the location and types of natural vegetation and habitats. Vegetation is among the most important characteristics of California=s natural environment. It provides food and shelter for the State=s terrestrial animal species, aids in the maintenance of aquatic habitats, and is the larger community that supports our many unique plant species. Vegetation acts as a filter for the state=s watershed lands, provides valuable forest products, economic benefits, and recreational opportunities to the citizens of California.

Natural resource agencies consider vegetation data as one of most important, if not the most important, data sets for their planning. For example, it is useful for:

- developing land management plans (such as National Forest plans);
- conducting watershed analysis;
- monitoring and evaluating the status, health, and trends of wildlife and other natural resources;
- assessing wildfire fuel loads and risks,
- making pre-fire and post-fire assessments and plans;
- modeling and predicting wildlife distributions and associated project impacts;
- identifying critical habitat and conservation priorities for endangered species;
- identifying potential habitat acquisitions;

- assessing risks of exotic species infestations;
- identifying restoration opportunities;
- planning for recreation and resource extraction; and
- siting of new facilities and infrastructure so as to minimize environmental impacts; and
- resolving conflicts prior to land use decisions that affect natural resources.

Status of Land Cover Mapping in California:

Natural resource professionals need the most detailed and accurate landcover data possible to improve their effectiveness and efficiency in making natural resource decisions. Developing such data for the 100 million acres of California is a tremendous challenge, both fiscally and logistically. As a result, no statewide vegetation data exists that adequately meets the needs of natural resource professionals for the purposes described above.

Because of the importance of this data, various public agencies and private organizations have funded their own individual land cover mapping efforts, mostly independently of each other, to meet their specific needs. These mapping efforts have used different mapping standards, making their integration across larger areas very difficult.

Statewide data sets have gradually improved over the years, with increased resolution and accuracy. The best data available is a mosaic of different data sets compiled by the California Department of Forestry and Fire Protection (CDF) from many sources, including CDF, the U.S. Forest Service, California Department of Fish and Game, California Department of Conservation, National Park Service, U.S. Geological Service, Bureau of Land Management, and the California Gap Analysis Program.

Although this CDF multi-source vegetation data is the best currently available, it still lacks the level of resolution required by many natural resource professionals. It also provides only those data fields held in common among the various mapping efforts. As a result, it does not provide all of the important fields or vegetation types required by various agencies.

Recognizing the need for improved land cover data and the need for increased cost sharing and collaboration, state, and federal agencies developed a formal agreement in 2000 laying out their intentions to work together on this need. An active team of representatives from signatory organizations has been meeting regularly over the past 18 months. They have developed common mapping standards and identified the most essential information (attributes) to capture for each map unit (polygon or pixel), based on each organization's most important business needs. The team has also created a crosswalk of rules for identifying vegetation types across existing classification systems. This crosswalk is an interim step until the more standardized National Vegetation Classification is completed and adopted by public agencies.

No current mapping effort fully uses all of these new mapping standards and attributes. As such, existing programs will have to modify their approaches to incorporate them, with uncertain associated costs for these changes. The team selected these standards and attributes to balance both existing business needs and costs. However, they need to be tested in a realistic mapping effort to fully ascertain their costs and implications for future mapping efforts. Some modifications may prove simple; others may be infeasible due to cost constraints.

Major Tasks

The Central Coast area provides an excellent opportunity for testing the new standards. A variety of state and federal agencies has common interests in improving vegetation data for this area. The area also contains sufficient vegetation diversity to adequately test the newly developed standards.

The entire project area has been subdivided into smaller geographic sub-areas. The mapping of each sub-area can proceed independently of the other and still achieve many of the project's objectives. Although funding for all sub-areas is desired, the project can still produce valuable products if funding is only raised for one or two sub-areas. These sub-areas are:

1. Fresno, Kings, and Kern County Coastal Hills – Develop baseline data
2. San Benito County – Develop baseline data
3. Monterey County – Update previous CDF/USFS data
4. San Luis Obispo County – Update previous CDF/USFS data and develop new baseline data

The project involves a process that integrates two parallel mapping efforts at different scales. Each of these efforts will follow standard methodologies that have been substantially tested on other parts of the state in recent years. These methodologies will be adjusted to accommodate the new mapping standards and to reflect collaboration and learning from each other. Key areas of substantial collaboration and cost-savings between both efforts are expected in the common acquisition of imagery, delineation of map polygons, shared fieldwork, and assessing accuracy of final products.

Medium-scale Mapping

The California Department of Forestry and Fire Protection and the U.S. Forest Service will coordinate the medium scale products. The main steps in this approach are summarized below. Appendix A provides additional detail. A detailed technical description of the approach is available upon request:

1. Inventory, and where necessary acquire, imagery and ancillary data.

2. Assess data and pre-process imagery to improve the quality and speed of the processing itself.
3. Create map polygons from the merged Landsat ETM/panchromatic data.
4. Label each map unit with a life form/land use (coarse classification) label, using an iterative process of computer modeling and evaluation by analysts.
5. Assign CALVEG type labels to polygons, using vegetation modeling and based on life form, terrain data, and any ancillary data sets that reliably define vegetation type distribution.
6. Apply image-processing techniques to classify mixed-pixels. Mixed pixels are those that contain at least 10 percent total tree cover and a relative hardwood component of 20 to 90 percent.
7. Label polygons with tree size classes.
8. Estimate canopy closure for tree and non-tree cover types
9. Develop metadata and quality-control the database
10. Assess accuracy by comparing vegetation maps against forest inventory plots, coordinated with the fine-scale assessment

Fine-scale Mapping

The California Department of Fish and Game and the California Native Plant Society will coordinate the fine-scale products. These products will cover up to 1.2 million acres, if adequate funding available, where more detailed mapping is needed, including areas with poorly understood vegetation types, areas with rare plant or animal species and/or areas increasingly threatened by development.

The team will decide on the actual extent and location of these fine-scale mapping efforts following in-depth discussions with county planners, staff from the Department of Fish and Game and other agencies, and representatives of interested non-governmental organizations. Preliminary discussions suggest the following areas may be of key importance:

- Areas within 2 miles of the coastline
- Northern San Luis Obispo County, due to rapid urban and residential growth patterns
- Most of San Benito County, due to a developing Habitat Conservation Planning (HCP) effort and Bureau of Land Management interest
- Western side of the Salinas Valley, especially along the wildland-urban interface

These fine-scale products will include substantially more fieldwork, more manual interpretation of aerial photography, and more detailed information about non-natural disturbance levels. The main steps in this approach are described below. Appendix B provides descriptions that are more detailed. A detailed technical description of the approach is available upon request:

1) Inventory and organize imagery and data
2) Refine vegetation classification based on field sampling
3) Delineate and label map polygons in sample field. Use this information to guide photo interpretation
4) Identify preliminary photo signature of vegetation units.
5) Conduct on-site visits to correlate the interpretation of the vegetation classification relative to the photo signatures
6) Interpret photos for entire project area.
7) Conduct a comprehensive quality control effort to ensure the accuracy and completeness of the photo interpretations and delineations
8) Conduct a formal field accuracy assessment of the map, coordinated with the medium-scale assessment
9) Final data processing and quality control

Deliverables

Medium-scale mapping

- Medium-scale land-cover GIS coverage of entire Central Coast project area, adhering to interagency MOU standards and integrated with the fine-scale product
- All final image classifications with manual edits
- CALVEG modeling rules and CWHR crosswalk logic
- All scripts and programs used for processing in the project
- Seamless project area 10-meter DEM where available (otherwise use 30-meter DEM)
- Ancillary layers compiled for the project
- Final database of project area, conforming to all mapping standards
- Map accuracy assessment

Fine-scale mapping

- Fine-scale land-cover GIS coverage of priority areas within the Central Coast project area, adhering to interagency MOU standards and integrated with the medium-scale product
- Digital list of vegetation alliances and cross walks to other vegetation classifications including modified Holland, CalVeg, and WHR
- Keys and description of vegetation types to alliance level
- Additions to the DFG Rapid Assessment database of all rapid assessment field samples collected in the central coast mapping area.
- Additions to the CVIS database of all full relevé samples collected in the central coast mapping area
- A final listing of vegetation types classified,
- Assessment of map accuracy
- A digital set of accuracy assessment plots in MS Access format

- Disturbance and land use information interpretable from air photos

Overall

Summary report describing:

- the process used for both scales of mapping
- lessons learned
- assessment of the feasibility and cost of implementing the interagency MOU standards
- recommendations for improving standards
- recommendations for improving the interagency collaborative process for future mapping efforts

Costs

The entire project, including medium-scale mapping of all sub-areas, will cost approximately $2.39 million. The chart below breaks out the costs per sub-area for the medium-scale effort and for the fine-scale effort. More detailed costs per tasks are available upon request. The California Department of Forestry and Fire Protection and the U.S. Forest Service are already committed to providing approximately $310,000 for this effort. This leaves a funding gap of approximately $2.08 million to complete the entire project area.

Actual costs may be substantially lower. Acquisition of aerial photographs constitutes approximately 35-60 % of the total costs for the medium-scale mapping, depending on whether the sub-area requires new baseline funding or updating of existing data. Additional research is needed to identify sources of existing photography that may be suitable to use in this effort. Use of such existing photography would substantially decrease total costs.

Project Sub-area	Total Cost per Sub-area	Total Acres	USFS/CDF in-kind	Funding Gap
Medium-scale Mapping				
Fresno, Kings, and Kern County Coastal Hills	$364,250	1,231,239	$217,485	$146,765
San Benito County	$262,350	886,798	$0	$262,350
Monterey County	$347,464	2,118,684	$49,292	$298,172
San Luis Obispo County	$550,275	2,123,462	$43,977	$506,298
Medium-scale Mapping Total	$1,524,339	6,360,183	$310,754	$1,213,585
Fine-scale Mapping	$864,000	1,200,000	$0	$360,000

(@$0.72/acre)				
Totals	**$2,388,339**		**$310,754**	**$2,077,585**

Costs vary between sub-areas depending on the level of mapping effort needed. New baseline mapping is needed for the Fresno, Kings, and Kern County Coastal Hills and for San Benito County. In both Monterey and parts of San Luis Obispo County, CDF and USFS have already produced medium-scale products using their existing cooperative mapping standards. Converting and updating these maps to the new draft standards identified by the interagency will be much less expensive than re-mapping and leverages existing work products in the most effective way. The remaining 1.5 million acres in San Luis Obispo County requires new baseline mapping.

Funding for fine-scale mapping is based on an estimated 1,200,000 acres of land requiring this level of mapping. Fieldwork is estimate to cost approximately 31 cents per acre and photo interpretation will cost approximately 41 cents per acre, or a total of 72 cents per acre (including accuracy assessment).

Schedule

The project is expected to start in January 2004, pending sufficient funding. The schedule below shows milestones for each of the integrated mapping efforts.

Timeline	Medium Scale	Fine Scale
January 2004	Acquired imagery and ancillary data; Inventoried and organized imagery and data	
February 2004	Assessed data and pre-processed imagery to improve the quality and speed of the processing itself	
March 2004	Created map polygons from the merged Landsat ETM/panchromatic data.	
April 2004		Refined vegetation classification based on field sampling; Delineated and labeled map polygons in sample field. Identified preliminary photo signature of vegetation units;
September 2004		Conducted on-site visits to correlate the interpretation of the vegetation classification relative to the photo signatures

April 2005	Assigned attributes for each map unit, including life form/land use label, CALVEG types, tree size classes, canopy closure. Classify mixed-pixels	Interpreted photos for entire project area; Conducted a comprehensive quality control effort to ensure the accuracy and completeness of the photo interpretations and delineations;
September 2005	Assess accuracy by comparing vegetation maps against forest inventory plots	Conducted a formal field accuracy assessment of the map
December 2005	Develop metadata and quality-control the database	Completed final data processing and quality control
December 2005	Completed summary report of the project	

Appendix A

Abbreviated description of mid-scale mapping methodology

1) **Acquire Imagery And Ancillary Data**
   a) Imagery includes Landsat ETM satellite imagery, 5-meter panchromatic imagery (IRS or SPOT5 data), 1:16,000 Color or Color IR photography for National Forest lands, 1:40,000 NAPP photography for non-National Forest lands, and Digital Ortho Quarter-Quads where available. Ancillary data includes administrative boundaries, digital elevation data, hydrography, transportation, plantation boundaries, fire history, state agricultural layers, lakes, and any existing vegetation data for project area

2) **Assess and Pre-process Data**
   a) Subdivide each sub-area into natural regions of relatively homogenous nature (physical and biological features), using the USDA Ecological Subsection classification and, where necessary, watershed boundaries. These areas serve as units for image classification and vegetation modeling and minimize spectral confusion due to abiotic factors such as soil parent material. For instance, two occurrences of the same vegetation type that exist on dissimilar soil parent material may have very dissimilar spectral signatures.
   b) Pre-process the imagery and ancillary data to improve the quality and speed of the processing itself. This includes spatially correctly mis-registered imagery, correcting anomalies in imagery, co-registering and merging the panchromatic data with Landsat ETM data, creating composite images from different ETM scenes, removing slivers and gaps, and creating slope, aspect, and elevation images for CALVEG and canopy modeling.
   c) Create map units (using image segmentation) from the merged Landsat ETM/panchromatic data. This provides the critical link between life form classification and a vegetation map that recognizes small but significant features in the landscape. This process typically creates a consistent, contiguous polygon coverage that respects spectral and spatial features, with individual polygons ranging in area from 2.5 to 20 acres for a given mapping landscape. Large areas of spectrally homogeneous, non-forest vegetation life forms such as agriculture and urban areas may form polygons exceeding 20 acres in size.

3) **Classify Life Forms**
   a) Conduct initial field reconnaissance to build familiarity with vegetation types and their distribution across the natural regions and to potential new vegetation types that are not currently defined.
   b) Integrate existing data to increase map accuracy and increase efficiency in the life form mapping process.

c) Label each map unit with a life form/land use label, using an iterative process of computer modeling and evaluation by analysts. Pixels are analyzed first, and then polygons are derived from that analysis to eliminate informational noise associated with pixel processing. The results are hand-edited to eliminate other anomalous errors.

4) **Classify CALVEG types**

a) Define a specific set of mappable CALVEG types for the project area, based on expert opinion, existing data, and field visits.
b) Assign CALVEG type labels to polygons, using vegetation modeling and based on life form, terrain data, and any ancillary data sets that reliably define vegetation type distribution. Vegetation modeling is broken into three major tasks: development of modeling rules by natural region, application and refinement of rules, and editing of anomalous, non-systematic error. CALVEG types are modeled to identify all primary conifer, hardwood, and shrub life forms as well as all secondary hardwood life form
c) Conduct additional fieldwork to identify edits needed to improve modeling rules or eliminate anomalous features.

5) **Classify Mixed Pixels, Including Resampling, and Regionalization**

a) Apply image-processing techniques to classify and label mixed-pixels. Mixed pixels are those that contain at least 10 percent total tree cover and a relative hardwood component of 20 to 90 percent.

6) **Classify Tree Sizes, including Resampling, and Regionalization**

a) Use panchromatic imagery, texture algorithms, and clustering algorithms to identify spatial variation among tree sizes. Label polygons with tree size classes.

7) **Estimate Canopy Closure**

a) Model canopy closure of tree types using canopy training data (from aerial photo interpretation samples), brightness and greenness imagery, mean slope and mean aspect. Canopy closure is a characteristic of an entire tree stand, not individual trees or small groups of trees.
b) Model vegetation cover of non-tree cover types. This step is an expansion of the current USFS/CDF mapping effort. Some uncertainties exist about the most appropriate methodologies and feasibility of mapping cover percentages for less obvious life forms (as reflected on remotely sensed data). The tree-canopy closure method will be evaluated for its usefulness with non-tree cover types. Standard image classification techniques may also be employed along with the use of vegetation indices derived from Landsat ETM data

8) **Finalize Database**

   a) Develop metadata, match edges between natural regions, identify incorrect attribute codes and illogical combinations of codes between map attributes, eliminate spatial anomalies, and visually inspect results.

9) **Assess Map Accuracy**

   a) Compare vegetation maps against forest inventory plots established as part of the Forest Service's Forest Inventory and Analysis (FIA) program. Strive to use the same plots as used in the fine-scale effort.

Appendix B

Abbreviated description of fine-scale mapping methodology

The fine-scale mapping effort is a combined effort of a field survey team and a photo interpreter team, both of which work interactively with each other during the process. The field survey team provides field data to guide the photo-interpretation and classification of map polygons. The photo interpreter team provides guidance about where additional field checking is needed.

1) **Inventory and Organize Imagery and Data** (Photo Interpreter Team)
   a) Inventory and organize all necessary imagery of the area usable within an ARC-View and ARC-Info Geographic Information System environment. This includes digital orthorectified aerial photographs of all areas to be mapped (Digital Orthophoto Quarter Quadrangles, true color photographs flown specifically for the study area, and diapositive photographs for the study area); existing digital vegetation maps; 30 m Digital Elevation Model; and all existing information on vegetation classification for the project area
   b) Upload digital files onto photo interpreter's computer and prepare data for the interactive photo interpretation process

2) **Refine Vegetation Classification based on Field Sampling** (Field team)
   a) Derive preliminary vegetation classification from published and unpublished information based on local data
   b) Conduct field reconnaissance to refine classification and become familiar with their unique aerial photo signatures
   c) Identify field sample sites
   d) Conduct field sampling
      i) Identify and document all plant communities to the alliance level or below, using the California Native Plant Society (CNPS) Vegetation Rapid Assessment Protocol
      ii) Describe new plant alliances and associations using CNPS relevé method
   e) Archive and classify vegetation data from sample sites
      i) Store rapid assessment data in a Microsoft Access database at CDFG
      ii) Store relevé data in the Web-based California Vegetation Information System
   f) Develop a vegetation classification based on field samples, using hierarchical classification techniques (e.g. TWINSPAN and Cluster Analysis).
      i) Develop decision rules for each association and use these to assign vegetation names to all existing data.
      ii) Develop key and descriptions for each vegetation type, as well as a crosswalk to the modified Holland classification system currently in use for central coast planning efforts will be made.

3) **Delineate Map Polygons in Sample Field Sites** (Field team)
   a) Delineate polygons of vegetation units across the study area by differentiating the aerial photo signatures that correspond to different vegetation types
   b) Assign vegetation attributes to each polygon, digitize and geo-reference the polygons, and edit for quality control
   c) Provide mapped information from sample sites to photo interpreter team

4) **Identify Preliminary Photo Signature** (Photo Interpreter Team)
   a) Use digital imagery and any ancillary photography covering the study area to delineate preliminary vegetation units. Use a combination of image segmentation provided by the USFS and heads-up (on-screen, as compared to formal digitizing tablets) digitizing techniques to collect a representative sampling of the photo signatures

5) **Field Reconnaissance** (Field team)
   a) Conduct on-site visits to correlate the interpretation of the vegetation classification relative to the photo signatures
   b) Establish repeatable correlations for use during the photo interpretation process. If necessary, the interpretations, mapping criteria, and/or classification will be modified.
   c) Field check areas not previously delineated on the aerial photos, such as areas between initially selected sites, areas of noteworthy or unusual significance, or areas the photo interpreter deems important in transit from site to site

6) **Photo Interpretation** (Photo Interpreter Team)
   a) After interim vegetation classification is developed, initiate photo interpretation.
   b) Assign a mapping label (such as alliance, alliance complex, or “super” alliance), disturbance, and density code to each polygon delineated during this task.
   c) Use descriptions and keys available for existing alliances to set the criteria for the interpretation of the vegetation units. Descriptions and keys for new classes that may emerge from the vegetation mapping process will be added by the field ecologists and provided to photo interpreters.
   d) Interpret vegetation units across the entire study area using heads-up digitizing techniques using custom ArcView editing tools. Delineate to a minimum mapping unit (MMU) size of two acres. Where necessary, such as areas with critical habitats and critical water sources, delineate units to one-acre sizes.
   e) Edgematch the vegetation delineations and codes between adjacent digital images to ensure that there are no gaps in the vegetation coverage.

7) **Quality Control Prior to Field Checking** (Photo Interpreter Team)

a) Conduct a comprehensive quality control effort to ensure the accuracy and completeness of the photo interpretations and delineations

8) **Field Check and Field Revisions** (Field Team)
   a) Generate field-check edit plots containing both the vegetation delineations and project imagery for all problematic polygons.
   b) Conduct field checks to ground-truth both specific polygons and general signatures on photos for which initial interpretation was complete.
   c) Conduct a formal field accuracy assessment of the map, using a random sampling strategy. The field ecology team will collect accuracy assessment data across the entire fine-scale mapping area. Data will be sufficient to assess accuracy of all vegetation types determined to be important in this fine-scale effort. Strive to use the same plots as used in the medium-scale effort.

9) **Quality Control After Field Checking** (Photo Interpreter Team)
   a) Produce a set of edit-plots to verify accuracy of data capture and any revisions made to the database because of the field check effort.

10) **Final Data Processing and Quality Control** (Photo Interpreter Team)
   a) Convert individual data files into ArcInfo coverages and join them to create a single coverage of the entire study area.
   b) Run automated quality checks to identify anomalies from joining process. Correct any resulting anomalies